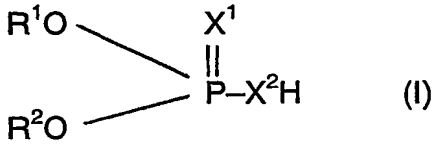
3167R-01

Claims

1. A method of lubricating an internal combustion engine and improving the efficiency of the emissions control system of the engine, the emissions control system being equipped with a catalyst containing exhaust gas after treatment device, the method comprising:

(A) selecting a lubricating oil composition comprising: a base oil; an alkali or alkaline earth metal-containing detergent; a metal salt of one or more phosphorus-containing compounds represented by the formula



(I)

wherein in formula (I), X^1 and X^2 are independently O or S, and R^1 and R^2 are independently hydrocarbyl groups, the average total number of carbon atoms in R^1 and R^2 for the one or more phosphorus-containing compounds being at least 10.4; and an acylated nitrogen containing compound having at least about 10 aliphatic carbon atoms and a TBN of at least about 2; the lubricating oil composition being characterized by a phosphorus concentration of up to about 0.12% by weight and the substantial absence of copper;

(B) adding the lubricating oil composition to the engine;

(C) operating the engine;

(D) generating a lean-phosphorus containing exhaust gas; and

(E) contacting the catalyst in the exhaust gas after treatment device with the lean-phosphorus containing exhaust gas.

2. The method of claim 1 wherein during step (A) the weight ratio of detergent metal to phosphorus in the lubricating oil composition is from about 0.5:1 to about 10:1.

3. The method of claim 1 wherein during step (A) the weight ratio of nitrogen to phosphorus in the lubricating oil composition is from about 0.3:1 to about 4:1.

4. The method of claim 1 wherein the lubricating oil composition has a viscosity of up to about 16.3 mm^2/s (cSt) at 100°C.

5. The method of claim 1 wherein the lubricating oil composition has an SAE Viscosity Grade of 0W, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W-50, 5W-60, 10W, 10W-20, 10W-30, 10W-40 or 10W-50.

6. The method of claim 1 wherein the lubricating oil composition has a viscosity grade of SAE 15W-40, SAE 30, SAE 40 or SAE 20W-50.

7. The method of claim 1 wherein the base oil comprises a mineral oil.

8. The method of claim 1 wherein the base oil comprises a poly-alpha-olefin or an oil derived from Fischer-Tropsch synthesized hydrocarbons.

9. The method of claim 1 wherein in formula (I), X^1 and X^2 are each S, and R^1 and R^2 are independently alkyl or alkenyl groups of about 6 to about 18 carbon atoms.

10. The method of claim 1 wherein in formula (I), X^1 and X^2 are each S, and R^1 and R^2 are aromatic groups.

11. The method of claim 1 wherein the metal used in the metal salt of a phosphorus containing compound is zinc.

12. The method of claim 1 wherein at least about 80% by weight of the phosphorus present in the lubricating oil composition is present in a compound represented by formula (I) wherein R^1 and R^2 are independently hydrocarbyl groups of about 6 to about 18 carbon atoms.

13. The method of claim 1 wherein the alkali or alkaline earth metal-containing detergent is a salt of an organic sulfur acid, carboxylic acid, lactone, phenol, or hydrocarbyl substituted saligenin.

14. The method of claim 1 wherein the alkali or alkaline earth metal-containing detergent is a salt of a linear oligomer or polymer containing

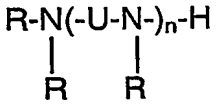
unsubstituted or substituted phenol units and unsubstituted or substituted salicylic units.

15. The method of claim 1 wherein the alkali or alkaline earth metal is sodium, lithium or calcium.

16. The method of claim 1 wherein the acylated nitrogen-containing compound is derived from a carboxylic acylating agent and at least one amino compound containing at least one -NH- group, the acylating agent being linked to the amino compound through an imido, amido, amidine or salt linkage.

17. The method of claim 16 wherein the carboxylic acylating agent is a mono- or polycarboxylic acid or anhydride containing an aliphatic hydrocarbyl substituent of at least about 30 carbon atoms.

18. The method of claim 16 wherein the amino compound is an alkylenepolyamine represented by the formula:



wherein U is an alkylene group of from about 2 to about 10 carbon atoms; each R is independently a hydrogen atom, a hydrocarbyl group, a hydroxy-substituted hydrocarbyl group, or an amine-substituted hydrocarbyl group containing up to about 30 carbon atoms; and n is 1 to about 14.

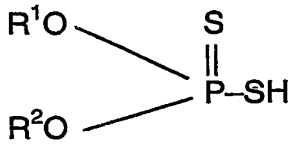
19. The method of claim 1 wherein the acylated nitrogen containing compound is a polyisobutene substituted succinimide.

20. The method of claim 1 wherein the lubricating oil composition further comprises a dispersant, corrosion-inhibiting agent, antioxidant, viscosity modifier, dispersant viscosity index modifier, pour point depressant, friction modifier, anti-wear agent, extreme pressure agent, fluidity modifier, copper passivator, anti-foam agent, or a mixture of two or more thereof.

21. The method of claim 1 wherein the lubricating oil composition is characterized by the substantial absence of magnesium.

22. A method of lubricating an internal combustion engine and improving the efficiency of the emissions control system of the engine, the emissions control system being equipped with a catalyst containing exhaust gas after treatment device, the method comprising:

(A) selecting a lubricating oil composition comprising: a base oil; an alkali or alkaline earth metal-containing detergent, the alkali or alkaline earth metal being sodium, lithium or calcium; a zinc salt of a phosphorus-containing compound represented by the formula



wherein R^1 and R^2 independently hydrocarbyl groups, the average total number of carbon atoms in R^1 and R^2 for the one or more phosphorus-containing compounds being at least 10.4; at least about 80% by weight of the phosphorus present in the lubricating oil composition being present in a compound represented by formula (I) wherein R^1 and R^2 are independently hydrocarbyl groups of about 6 to about 18 carbon atoms; and a polyisobutene substituted succinimide having a TBN of about 5 to about 30, the polyisobutene substituent having a number average molecular weight in the range of about 700 to about 3000; the lubricating oil composition being characterized by a phosphorus concentration of no more than about 0.12% by weight and the substantial absence of copper;

(B) adding the lubricating oil composition to the engine;

(C) operating the engine;

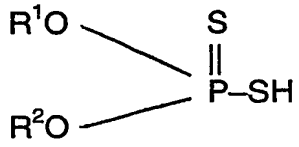
(D) generating a lean-phosphorus containing exhaust gas; and

(E) contacting the catalyst in the exhaust gas after treatment device with the lean-phosphorus containing exhaust gas.

23. A method of lubricating an internal combustion engine and improving the efficiency of the emissions control system of the engine, the emissions control

system being equipped with a catalyst containing exhaust gas after treatment device, the method comprising:

(A) selecting a lubricating oil composition comprising: a base oil; an alkali or alkaline earth metal-containing detergent, the alkali or alkaline earth metal being sodium, lithium or calcium; a zinc salt of a phosphorus-containing compound represented by the formula



wherein R^1 and R^2 are 4-methyl-2-pentyl; and a polyisobutene substituted succinimide having a TBN of about 5 to about 30, the polyisobutene substituent having a number average molecular weight in the range of about 700 to about 3000; the lubricating oil composition being characterized by a phosphorus concentration of no more than about 0.12% by weight and the substantial absence of copper;

(B) adding the lubricating oil composition to the engine;

(C) operating the engine;

(D) generating a lean-phosphorus containing exhaust gas; and

(E) contacting the catalyst in the exhaust gas after treatment device with the lean-phosphorus containing exhaust gas.

24. The method of claim 1 wherein at least 70 mole percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt are derived from secondary alcohols.

25. The method of claim 1 wherein less than 34 mole percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms.

26. The method of claim 1 wherein the lubricating oil composition is characterized by a phosphorus content of up to about 0.08 percent by weight phosphorus.

27. The method of claim 23 wherein the lubricating oil composition is characterized by a phosphorus content of up to about 0.08 percent by weight phosphorus.

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28. The method of claim 1 wherein up to about 40 percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms.

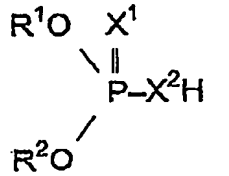
29. The method of claim 1 wherein from about 16 to about 34 percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms.

30. The method of claim 1 wherein up to about 40 percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms and at least 60 mole percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt are derived from secondary alcohols.

31. The method of claim 1 wherein from about 16 to about 34 percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms and at least 60 mole percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt are derived from secondary alcohols.

32. A method of lubricating an internal combustion engine and improving the efficiency of the emissions control system of the engine, the emissions control system being equipped with a catalyst containing exhaust gas after treatment device, the method comprising:

(A) selecting a lubricating oil composition comprising: a base oil; an alkali or alkaline earth metal-containing detergent; a metal salt of one or more phosphorus-containing compounds represented by the formula



(I)

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wherein in formula (I), X^1 and X^2 are independently O or S, and R^1 and R^2 are independently hydrocarbyl groups, the average total number of carbon atoms in R^1 and R^2 for the one or more phosphorus-containing compounds is at least 10.4, up to about 40 percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt contain 4 or fewer carbon atoms, and at least 60 mole percent of all the R^1 and R^2 groups supplied by the phosphorus-containing metal salt are derived from secondary alcohols; and an acylated nitrogen containing compound having at least about 10 aliphatic carbon atoms and a TBN of at least about 2; the lubricating oil composition being characterized by a phosphorus concentration of up to about 0.12% by weight and the substantial absence of copper;

(B) adding the lubricating oil composition to the engine;

(C) operating the engine;

(D) generating a lean-phosphorus containing exhaust gas; and

(E) contacting the catalyst in the exhaust gas after treatment device with the lean-phosphorus containing exhaust gas.